CHAPTER 20 (Odd)

1. a. $\omega_s = \dfrac{1}{\sqrt{LC}} = \dfrac{1}{\sqrt{1\text{ H})(16\ \mu\text{F})}} = \mathbf{250\ rad/s}$

$f_s = \dfrac{\omega_s}{2\pi} = \dfrac{250\text{ rad/s}}{2\pi} = \mathbf{39.79\ Hz}$

b. $\omega_s = \dfrac{1}{\sqrt{(0.5\text{ H})(0.16\ \mu\text{F})}} = \mathbf{3535.53\ rad/s}$

$f_s = \dfrac{\omega_s}{2\pi} = \dfrac{3535.53\text{ rad/s}}{2\pi} = \mathbf{562.7\ Hz}$

c. $\omega_s = \dfrac{1}{\sqrt{(0.28\text{ mH})(7.46\ \mu\text{F})}} = \mathbf{21{,}880\ rad/s}$

$f_s = \dfrac{\omega_s}{2\pi} = \dfrac{21{,}880\text{ rad/s}}{2\pi} = \mathbf{3482.31\ Hz}$

3. a. $X_L = \mathbf{40\ \Omega}$

b. $I = \dfrac{E}{Z_{T_s}} = \dfrac{20\text{ mV}}{2\ \Omega} = \mathbf{10\ mA}$

c. $V_R = IR = (10\text{ mA})(2\ \Omega) = \mathbf{20\ mV} = \text{E}$

$V_L = IX_L = (10\text{ mA})(40\ \Omega) = \mathbf{400\ mV}$

$V_C = IX_C = (10\text{ mA})(40\ \Omega) = \mathbf{400\ mV}$

$V_L = V_C = 20\ V_R$

d. $Q_s = \dfrac{X_L}{R} = \dfrac{40\ \Omega}{2\ \Omega} = \mathbf{20}$ (high Q)

e. $X_L = 2\pi fL,\ L = \dfrac{X_L}{2\pi f} = \dfrac{40\ \Omega}{2\pi(5\text{ kHz})} = \mathbf{1.27\ mH}$

$X_C = \dfrac{1}{2\pi fC},\ C = \dfrac{1}{2\pi fX_C} = \dfrac{1}{2\pi(5\text{ kHz})(40\ \Omega)} = \mathbf{0.796\ \mu F}$

f. $BW = \dfrac{f_s}{Q_s} = \dfrac{5\text{ kHz}}{20} = \mathbf{250\ Hz}$

g. $f_2 = f_s + \dfrac{BW}{2} = 5\text{ kHz} + \dfrac{0.25\text{ kHz}}{2} = \mathbf{5.125\ kHz}$

$f_1 = f_s - \dfrac{BW}{2} = 5\text{ kHz} - \dfrac{0.25\text{ kHz}}{2} = \mathbf{4.875\ kHz}$

5. a. $BW = f_s/Q_s = 6000\text{ Hz}/15 = \mathbf{400\ Hz}$

b. $f_2 = f_s + \dfrac{BW}{2} = 6000 \text{ Hz} + 200 \text{ Hz} = \mathbf{6200 \text{ Hz}}$

$f_1 = f_s - \dfrac{BW}{2} = 6000 \text{ Hz} - 200 \text{ Hz} = \mathbf{5800 \text{ Hz}}$

c. $Q_s = \dfrac{X_L}{R} \Rightarrow X_L = Q_s R = (15)(3\ \Omega) = \mathbf{45\ \Omega} = X_C$

d. $P_{HPF} = \dfrac{1}{2}P_{max} = \dfrac{1}{2}(I^2R) = \dfrac{1}{2}(0.5\text{ A})^2\, 3\Omega = \mathbf{375 \text{ mW}}$

7. a. $BW = \dfrac{f_s}{Q_s} \Rightarrow Q_s = f_s/BW = 2000 \text{ Hz}/200 \text{ Hz} = \mathbf{10}$

b. $Q_s = \dfrac{X_L}{R} \Rightarrow X_L = Q_s R = (10)(2\ \Omega) = \mathbf{20\ \Omega}$

c. $L = \dfrac{X_L}{2\pi f} = \dfrac{20\ \Omega}{(6.28)(2 \text{ kHz})} = \mathbf{1.59 \text{ mH}}$

$C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{(6.28)(2 \text{ kHz})(20\ \Omega)} = \mathbf{3.98\ \mu F}$

d. $f_2 = f_s + BW/2 = 2000 \text{ Hz} + 100 \text{ Hz} = \mathbf{2100 \text{ Hz}}$

$f_1 = f_s - BW/2 = 2000 \text{ Hz} - 100 \text{ Hz} = \mathbf{1900 \text{ Hz}}$

9. $I_M = \dfrac{E}{R} \Rightarrow R = \dfrac{E}{I_M} = \dfrac{5 \text{ V}}{500 \text{ mA}} = \mathbf{10\ \Omega}$

$BW = f_s/Q_s \Rightarrow Q_s = f_s/BW = 8400 \text{ Hz}/120 \text{ Hz} = 70$

$Q_s = \dfrac{X_L}{R} \Rightarrow X_L = Q_s R = (70)(10\ \Omega) = \mathbf{700\ \Omega}$

$X_C = X_L = \mathbf{700\ \Omega}$

$L = \dfrac{X_L}{2\pi f} = \dfrac{700\ \Omega}{(2\pi)(8.4 \text{ kHz})} = \mathbf{13.26 \text{ mH}}$

$C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{(2\pi)(8.4 \text{ kHz})(0.7 \text{ k}\Omega)} = \mathbf{27.07 \text{ nF}}$

$f_2 = f_s + BW/2 = 8400 \text{ Hz} + 120 \text{ Hz}/2 = \mathbf{8460 \text{ Hz}}$

$f_1 = f_s - BW/2 = 8400 \text{ Hz} - 60 \text{ Hz} = \mathbf{8340 \text{ Hz}}$

11. a. $f_s = \dfrac{\omega_s}{2\pi} = \dfrac{2\pi \times 10^6 \text{ rad/s}}{2\pi} = \mathbf{1 \text{ MHz}}$

b. $\dfrac{f_2 - f_1}{f_s} = 0.16 \Rightarrow BW = f_2 - f_1 = 0.16 f_s = 0.16(1 \text{ MHz}) = \mathbf{160 \text{ kHz}}$

c. $P = \dfrac{V_R^2}{R} \Rightarrow R = \dfrac{V_R^2}{P} = \dfrac{(120\text{ V})^2}{20\text{ W}} = \mathbf{720\ \Omega}$

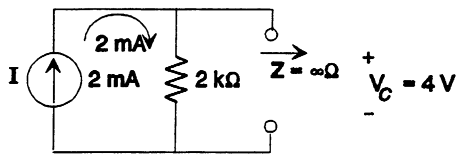
$BW = \dfrac{R}{2\pi L} \Rightarrow L = \dfrac{R}{2\pi BW} = \dfrac{720\ \Omega}{(6.28)(160\text{ kHz})} = \mathbf{0.7162\ mH}$

$f_s = \dfrac{1}{2\pi\sqrt{LC}} \Rightarrow C = \dfrac{1}{4\pi^2 f_s^2 L} = \dfrac{1}{4\pi^2(10^6\text{ Hz})^2(0.7162\text{ mH})} = \mathbf{35.37\ pF}$

d. $Q_\ell = \dfrac{X_L}{R_\ell} = 80 \Rightarrow R_\ell = \dfrac{X_L}{80} = \dfrac{2\pi f_s L}{80} = \dfrac{2\pi(10^6\text{ Hz})(0.7162\text{ mH})}{80} = \mathbf{56.25\ \Omega}$

13. a. $f_p = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(0.1\text{ mH})(10\text{ nF})}} = \mathbf{159.155\ kHz}$

b.



c. $I_L = \dfrac{V_L}{X_L} = \dfrac{4\text{ V}}{2\pi f_p L} = \dfrac{4\text{ V}}{100\ \Omega} = \mathbf{40\ mA}$

$I_C = \dfrac{V_L}{X_C} = \dfrac{4\text{ V}}{1/2\pi f_p C} = \dfrac{4\text{ V}}{100\ \Omega} = \mathbf{40\ mA}$

d. $Q_p = \dfrac{R_s}{X_{L_p}} = \dfrac{2\text{ k}\Omega}{2\pi f_p L} = \dfrac{2\text{ k}\Omega}{100\ \Omega} = \mathbf{20}$

15. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(0.1\text{ mH})(2\ \mu\text{F})}} = \mathbf{11{,}253.95\ Hz}$

b. $Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{2\pi f_s L}{R_\ell} = \dfrac{2\pi(11{,}253.95\text{ Hz})(0.1\text{ mH})}{4\ \Omega} = \mathbf{1.77}$ (low Q_ℓ)

c. $f_p = f_s\sqrt{1 - \dfrac{R_\ell^2 C}{L}} = 11{,}253.95\text{ Hz}\sqrt{1 - \dfrac{(4\ \Omega)^2\ 2\ \mu\text{F}}{0.1\text{ mH}}} = 11{,}253.95\text{ Hz}(0.825)$

$= \mathbf{9{,}280.24\ Hz}$

$f_m = f_s\sqrt{1 - \dfrac{1}{4}\left[\dfrac{R_\ell^2 C}{L}\right]} = 11{,}253.95\text{ Hz}\sqrt{1 - \dfrac{1}{4}\left[\dfrac{(4\ \Omega)^2\ 2\ \mu\text{F}}{0.1\text{ mH}}\right]}$

$= 11{,}253.95\text{ Hz}(0.996) = \mathbf{10{,}794.41\ Hz}$

d. $X_L = 2\pi f_p L = 2\pi(9{,}280.24\text{ Hz})(0.1\text{ mH}) = \mathbf{5.83\ \Omega}$

$$X_C = \frac{1}{2\pi f_p C} = \frac{1}{2\pi(9{,}280.24\text{ Hz})(2\ \mu\text{F})} = \mathbf{8.57\ \Omega}$$

$X_L \neq X_C$, $X_C > X_L$

e. $$Z_{T_p} = R_s \| R_p = R_s \| \left[\frac{R_\ell^2 + X_L^2}{R_\ell}\right] = \frac{R_\ell^2 + X_L^2}{R_\ell} = \frac{(4\ \Omega)^2 + (5.83\ \Omega)^2}{4\ \Omega} = \mathbf{12.5\ \Omega}$$

f. $V_C = IZ_{T_p} = (2\text{ mA})(12.5\ \Omega) = \mathbf{25\ mV}$

g. Since $R_s = \infty\ \Omega$ $$Q_p = Q_\ell = \frac{X_L}{R_\ell} = \frac{2\pi f_p L}{R_\ell} = \frac{2\pi(9{,}280.24\text{ Hz})(0.1\text{ mH})}{4\ \Omega} = \mathbf{1.46}$$

$$BW = \frac{f_p}{Q_p} = \frac{9{,}280.24\text{ Hz}}{1.46} = \mathbf{6.356\ kHz}$$

h. $$I_C = \frac{V_C}{X_C} = \frac{25\text{ mV}}{8.57\ \Omega} = \mathbf{2.92\ mA}$$

$$I_L = \frac{V_L}{Z_{R\text{-}L}} = \frac{V_C}{R_\ell + jX_L} = \frac{25\text{ mV}}{4\ \Omega + j5.83\ \Omega} = \frac{25\text{ mV}}{7.07\ \Omega} = \mathbf{3.54\ mA}$$

17. a. $Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{30\ \Omega}{2\ \Omega} = 15$ (use approximate approach): $X_C = X_L = \mathbf{30\ \Omega}$

b. $Z_{T_p} = R_s \| Q_\ell^2 R_\ell = 450\ \Omega \| (15)^2\, 2\ \Omega = 450\ \Omega \| 450\ \Omega = \mathbf{225\ \Omega}$

c. $\mathbf{E} = \mathbf{I}\mathbf{Z}_{T_p} = (80\text{ mA}\ \angle 0°)(225\ \Omega\ \angle 0°) = \mathbf{18\ V\ \angle 0°}$

$$\mathbf{I}_C = \frac{\mathbf{E}}{X_C \angle -90°} = \frac{18\text{ V}\ \angle 0°}{30\ \Omega\ \angle -90°} = \mathbf{0.6\ A\ \angle 90°}$$

$$\mathbf{I}_L = \frac{\mathbf{E}}{\mathbf{Z}_{R\text{-}L}} = \frac{18\text{ V}\ \angle 0°}{2\ \Omega + j30\ \Omega} = \frac{18\text{ V}\ \angle 0°}{30.07\ \Omega\ \angle 86.19°} \cong \mathbf{0.6\ A\ \angle -86.19°}$$

d. $$X_L = 2\pi f_p L,\ L = \frac{X_L}{2\pi f_p} = \frac{30\ \Omega}{2\pi(20 \times 10^3\text{ Hz})} = \mathbf{0.239\ mH}$$

$$X_C = \frac{1}{2\pi f_p C},\ C = \frac{1}{2\pi f_p X_C} = \frac{1}{2\pi(20 \times 10^3\text{ Hz})(30\ \Omega)} = \mathbf{265.26\ nF}$$

e. $$Q_p = \frac{Z_{T_p}}{X_L} = \frac{225\ \Omega}{30\ \Omega} = \mathbf{7.5},\ BW = \frac{f_p}{Q_p} = \frac{20{,}000\text{ Hz}}{7.5} = \mathbf{2.67\ kHz}$$

19. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(0.5\text{ mH})(1\ \mu\text{F})}} = \mathbf{7.118\ kHz}$

$$f_p = f_s\sqrt{1 - \frac{R_\ell^2 C}{L}} = 7.118\text{ kHz}\sqrt{1 - \frac{(8\ \Omega)^2(1\ \mu\text{F})}{0.5\text{ mH}}} = 7.118\text{ kHz}(0.9338) = \mathbf{6.647\ kHz}$$

$$f_m = f_s\sqrt{1 - \frac{1}{4}\left[\frac{R_\ell^2 C}{L}\right]} = 7.118\text{ kHz}\sqrt{1 - \frac{1}{4}\left[\frac{(8\ \Omega)^2(1\ \mu\text{F})}{0.5\text{ mH}}\right]} = 7.118\text{ kHz}\ (0.9839)$$
$$= \mathbf{7\ kHz}$$

b. $X_L = 2\pi f_p L = 2\pi(6.647\text{ kHz})(0.5\text{ mH}) = 20.88\ \Omega$

$X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(6.647\text{ kHz})(1\ \mu\text{F})} = 23.94\ \Omega$

$X_C > X_L$ (low Q)

c. $Z_{T_p} = R_s \| R_p = R_s \| \dfrac{R_\ell^2 + X_L^2}{R_\ell} = 500\ \Omega \| \dfrac{(8\ \Omega)^2 + (20.88\ \Omega)^2}{8\ \Omega} = 500\ \Omega \| 62.5\ \Omega$

$= \mathbf{55.56\ \Omega}$

d. $Q_p = \dfrac{Z_{T_p}}{X_{L_p}} = \dfrac{55.56\ \Omega}{23.94\ \Omega} = \mathbf{2.32}$

$BW = \dfrac{f_p}{Q_p} = \dfrac{6.647\text{ kHz}}{2.32} = \mathbf{2.865\ kHz}$

e. One method: $V_C = IZ_{T_p} = (40\text{ mA})(55.56\ \Omega) = 2.22\text{ V}$

$I_C = \dfrac{V_C}{X_C} = \dfrac{2.22\text{ V}}{23.94\ \Omega} = \mathbf{92.73\ mA}$

$I_L = \dfrac{|V_C|}{|R_\ell + jX_L|} = \dfrac{2.22\text{ V}}{|8 + j20.88|} = \dfrac{2.22\text{ V}}{22.36\ \Omega} = \mathbf{99.28\ mA}$

f. $V_C = \mathbf{2.22\ V}$

21. a. $Q_\ell = 20 > 10 \therefore f_p = f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(200\text{ mH})(10\text{ nF})}} = \mathbf{3558.81\ Hz}$

b. $Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{2\pi fL}{R_\ell} \Rightarrow R_\ell = \dfrac{2\pi fL}{Q_\ell} = \dfrac{2\pi(3558.81\text{ Hz})(0.2\text{ H})}{20} = 223.61\ \Omega$

$Z_{T_p} = R_s \| R_p = R_s \| Q_\ell^2 R_\ell = 40\text{ k}\Omega \| (20)^2\ 223.61\ \Omega$

$Z_{T_p} = 27.64\text{ k}\Omega$

$V_C = IZ_{T_p} = (5\text{ mA})(27.64\text{ k}\Omega) = \mathbf{138.2\ V}$

c. $P = I^2R = (5\text{ mA})^2 27.64\text{ k}\Omega = \mathbf{691\ mW}$

d. $$Q_p = \frac{R}{X_L} = \frac{R_s \| R_p}{X_L} = \frac{27.64\text{ k}\Omega}{2\pi(3558.81\text{ Hz})(0.2\text{ H})} = \mathbf{6.18}$$

$$BW = \frac{f_p}{Q_p} = \frac{3558.81\text{ Hz}}{6.18} = \mathbf{575.86\text{ Hz}}$$

23. a. $$X_C = \frac{R_\ell^2 + X_L^2}{X_L} \Rightarrow X_L^2 - X_L X_C + R_\ell^2 = 0$$

$$X_L^2 - 100\,X_L + 144 = 0$$

$$X_L = \frac{-(-100) \pm \sqrt{(100)^2 - 4(1)(144)}}{2}$$

$$= 50\ \Omega \pm \frac{\sqrt{10^4 - 576}}{2} = 50\ \Omega \pm 48.54\ \Omega$$

$$X_L = \mathbf{98.54\ \Omega} \text{ or } 1.46\ \Omega$$

b. $$Q_\ell = \frac{X_L}{R_\ell} = \frac{98.54\ \Omega}{12\ \Omega} = \mathbf{8.21}$$

c. $$Q_p = \frac{R_s \| R_p}{X_{L_p}} = \frac{40\text{ k}\Omega \left\| \dfrac{R_\ell^2 + X_L^2}{R_\ell}\right.}{X_C} = \frac{40\text{ k}\Omega \left\| \dfrac{(12\ \Omega)^2 + (98.54\ \Omega)^2}{12\ \Omega}\right.}{100\ \Omega}$$

$$= \frac{40\text{ k}\Omega \| 821.18\ \Omega}{100\ \Omega} = \frac{804.66\ \Omega}{100\ \Omega} = \mathbf{8.05}$$

$$BW = f_p/Q_p \Rightarrow f_p = Q_p BW = (8.05)(1\text{ kHz}) = \mathbf{8.05\text{ kHz}}$$

d. $$V_{C_{\max}} = IZ_{T_p} = (6\text{ mA})(804.66\ \Omega) = \mathbf{4.83\text{ V}}$$

e. $$f_2 = f_p + BW/2 = 8.05\text{ kHz} + \frac{1\text{ kHz}}{2} = \mathbf{8.55\text{ kHz}}$$

$$f_1 = f_p - BW/2 = 8.05\text{ kHz} - \frac{1\text{ kHz}}{2} = \mathbf{7.55\text{ kHz}}$$

25. $$Q_\ell = \frac{X_L}{R_\ell} = \frac{2\pi f_p L}{R_\ell} \Rightarrow R_\ell = \frac{2\pi f_p L}{Q_\ell} = \frac{2\pi(20\text{ kHz})(2\text{ mH})}{80} = \mathbf{3.14\ \Omega}$$

$$BW = f_p/Q_p \Rightarrow Q_p = f_p/BW = 20\text{ kHz}/1.8\text{ kHz} = \mathbf{11.11}$$

High $Q \therefore$ $$f_p \cong f_s = \frac{1}{2\pi\sqrt{LC}} \Rightarrow C = \frac{1}{4\pi^2 f_p^2 L} = \frac{1}{4\pi^2(20\text{ kHz})^2\ 2\text{ mH}} = \mathbf{31.66\text{ nF}}$$

$$Q_p = \frac{R}{X_C} \Rightarrow R = Q_p X_C = \frac{Q_p}{2\pi f_p C} = \frac{11.11}{2\pi(20\text{ kHz})(31.66\text{ nF})} = \mathbf{2.793\text{ k}\Omega}$$

$$R_p = Q_\ell^2 R_\ell = (80)^2\ 3.14\ \Omega = 20.1\text{ k}\Omega$$

$$R = R_s \| R_p = \frac{R_s R_p}{R_s + R_p} \Rightarrow R_s = \frac{R_p R}{R_p - R} = \frac{(20.1\text{ k}\Omega)(2.793\text{ k}\Omega)}{20.1\text{ k}\Omega - 2.793\text{ k}\Omega} = \mathbf{3.244\text{ k}\Omega}$$

27. a. $$f_s = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(200\ \mu\text{H})(2\text{ nF})}} = 251.65\text{ kHz}$$

$$Q_\ell = \frac{X_L}{R_\ell} = \frac{2\pi(251.65\text{ kHz})(200\ \mu\text{H})}{20\ \Omega} = 15.81 \geq 10$$

$$\therefore f_p = f_s = \mathbf{251.65\text{ kHz}}$$

b. $$Z_{T_p} = R_s \| Q_\ell^2 R_\ell = 40\text{ k}\Omega \| (15.81)^2\, 20\ \Omega = \mathbf{4.444\text{ k}\Omega}$$

c. $$Q_p = \frac{R_s \| Q_\ell^2 R_\ell}{X_L} = \frac{4.444\text{ k}\Omega}{316.23\ \Omega} = \mathbf{14.05}$$

d. $$BW = \frac{f_p}{Q_p} = \frac{251.65\text{ kHz}}{14.05} = \mathbf{17.91\text{ kHz}}$$

e. **20 μH, 20 nF**

f_s the same since product LC the same

$f_s = 251.65$ kHz

$$Q_\ell = \frac{X_L}{R_\ell} = \frac{2\pi(251.65\text{ kHz})(20\ \mu\text{H})}{20\ \Omega} = 1.581$$

Low Q_ℓ:

$$f_p = f_s\sqrt{1 - \frac{R_\ell^2 C}{L}} = (251.65\text{ kHz})\sqrt{1 - \frac{(20\ \Omega)^2(20\text{ nF})}{20\ \mu\text{H}}}$$

$$= (251.65\text{ kHz})(0.775) = \mathbf{194.93\text{ kHz}}$$

$$X_L = 2\pi f_p L = 2\pi(194.93\text{ kHz})(20\ \mu\text{H}) = 24.496\ \Omega$$

$$R_p = \frac{R_\ell^2 + X_L^2}{R_\ell} = \frac{(20\ \Omega)^2 + (24.496\ \Omega)^2}{20\ \Omega} = 50\ \Omega$$

$$Z_{T_p} = R_s \| R_p = 40\text{ k}\Omega \| 50\ \Omega = \mathbf{49.94\ \Omega}$$

$$Q_p = \frac{R}{X_L} = \frac{49.94\ \Omega}{24.496\ \Omega} = \mathbf{2.04}$$

$$BW = \frac{f_p}{Q_p} = \frac{194.93\text{ kHz}}{2.04} = \mathbf{95.55\text{ kHz}}$$

f. **0.4 mH, 1 nF**

$f_s = 251.65$ kHz since LC product the same

$$Q_\ell = \frac{X_L}{R_\ell} = \frac{2\pi(251.65\text{ kHz})(0.4\text{ mH})}{20\ \Omega} = 31.62 \geq 10$$

$$\therefore f_p = f_s = \mathbf{251.65\text{ kHz}}$$

$$Z_{T_p} = R_s \| Q_\ell^2 R_\ell = 40\text{ k}\Omega \| (31.62)^2\, 20\ \Omega = 40\text{ k}\Omega \| (\cong 20\text{ k}\Omega) \cong \mathbf{13.33\text{ k}\Omega}$$

$$Q_p = \frac{R_s \| Q_\ell^2 R_\ell}{X_L} = \frac{13.33\text{ k}\Omega}{632.47\ \Omega} = \mathbf{21.08}$$

$$BW = \frac{f_p}{Q_p} = \frac{251.65\text{ kHz}}{21.08} = \mathbf{11.94\text{ kHz}}$$

g. Network $\dfrac{L}{C} = \dfrac{200\ \mu\text{H}}{2\text{ nF}} = \mathbf{100 \times 10^3}$

part (e) $\dfrac{L}{C} = \dfrac{20\ \mu\text{H}}{20\text{ nF}} = \mathbf{1 \times 10^3}$

part (f) $\dfrac{L}{C} = \dfrac{0.4\text{ mH}}{1\text{ nF}} = \mathbf{400 \times 10^3}$

h. Yes, as $\dfrac{L}{C}$ ratio increased BW decreased.

Also, $V_p = IZ_{T_p}$, and for a fixed I, Z_{T_p} and therefore V_p will increase with increase in the L/C ratio.

CHAPTER 20 (Even)

2. a. $X_C = \mathbf{30\ \Omega}$ b. $Z_{T_s} = \mathbf{10\ \Omega}$ c. $I = \dfrac{E}{Z_{T_s}} = \dfrac{50\text{ mV}}{10\ \Omega} = \mathbf{5\ mA}$

d. $V_R = IR = (5\text{ mA})(10\ \Omega) = \mathbf{50\ mV} = \text{E}$
$V_L = IX_L = (5\text{ mA})(30\ \Omega) = \mathbf{150\ mV}$
$V_C = IX_C = (5\text{ mA})(30\ \Omega) = \mathbf{150\ mV}$
$V_L = V_C$

e. $Q_s = \dfrac{X_L}{R} = \dfrac{30\ \Omega}{10\ \Omega} = \mathbf{3}$ (low Q) f. $P = I^2R = (5\text{ mA})^2\, 10\ \Omega = \mathbf{0.25\ mW}$

4. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} \Rightarrow L = \dfrac{1}{(2\pi f_s)^2 C} = \dfrac{1}{(2\pi\, 1.8\text{ kHz})^2\, 2\ \mu\text{F}} = \mathbf{3.91\ mH}$

b. $X_L = 2\pi fL = 2\pi(1.8\text{ kHz})(3.91\text{ mH}) = \mathbf{44.2\ \Omega}$
$X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(1.8\text{ kHz})(2\ \mu\text{F})} = \mathbf{44.2\ \Omega}$
$X_L = X_C$

c. $E_{\text{rms}} = (0.707)(20\text{ mV}) = 14.14\text{ mV}$
$I_{\text{rms}} = \dfrac{E_{\text{rms}}}{R} = \dfrac{14.14\text{ mV}}{4.7\ \Omega} = \mathbf{3.01\ mA}$

d. $P = I^2R = (3.01\text{ mA})^2\, 4.7\ \Omega = \mathbf{42.58\ \mu W}$

e. $S_T = P_T = \mathbf{42.58\ \mu VA}$ f. $F_p = \mathbf{1}$

g. $Q_s = \dfrac{X_L}{R} = \dfrac{44.2\ \Omega}{4.7\ \Omega} = \mathbf{9.4}$
$BW = \dfrac{f_s}{Q_s} = \dfrac{1.8\text{ kHz}}{9.4} = \mathbf{191.49\ Hz}$

h. $$f_2 = \frac{1}{2\pi}\left[\frac{R}{2L} + \frac{1}{2}\sqrt{\left[\frac{R}{L}\right]^2 + \frac{4}{LC}}\right]$$

$$= \frac{1}{2\pi}\left[\frac{4.7\ \Omega}{2(3.91\text{ mH})} + \frac{1}{2}\sqrt{\left[\frac{4.7\ \Omega}{3.91\text{ mH}}\right]^2 + \frac{4}{(3.91\text{ mH})(2\ \mu\text{F})}}\right]$$

$$= \frac{1}{2\pi}[601.02 + 11.324 \times 10^3]$$

$$= \mathbf{1897.93\ Hz}$$

$$f_1 = \frac{1}{2\pi}\left[-\frac{R}{2L} + \frac{1}{2}\sqrt{\left(\frac{R}{L}\right)^2 + \frac{4}{LC}}\right]$$

$$= \frac{1}{2\pi}[-601.02 + 11.324 \times 10^3]$$

$$= \mathbf{1.707\ kHz}$$

$$P_{HPF} = \frac{1}{2}P_{max} = \frac{1}{2}(42.58\ \mu W) = \mathbf{21.29\ \mu W}$$

6. a. $L = \dfrac{X_L}{2\pi f} = \dfrac{200\ \Omega}{2\pi(10^4\ Hz)} = 3.185\ mH$

$BW = \dfrac{R}{2\pi L} = \dfrac{5\ \Omega}{2\pi(3.185\ mH)} \cong \mathbf{250\ Hz}$

or $Q_s = \dfrac{X_L}{R} = \dfrac{X_C}{R} = \dfrac{200\ \Omega}{5\ \Omega} = 40,\ BW = \dfrac{f_s}{Q_s} = \dfrac{10{,}000\ Hz}{40} = \mathbf{250\ Hz}$

b. $f_2 = f_s + BW/2 = 10{,}000\ Hz + 250\ Hz/2 = \mathbf{10{,}125\ Hz}$
$f_1 = f_s - BW/2 = 10{,}000\ Hz - 125\ Hz = \mathbf{9{,}875\ Hz}$

c. $Q_s = \dfrac{X_L}{R} = \dfrac{200\ \Omega}{5\ \Omega} = \mathbf{40}$

d. $\mathbf{I} = \dfrac{E\angle 0°}{R\angle 0°} = \dfrac{30\ V\ \angle 0°}{5\ \Omega\ \angle 0°} = 6\ A\ \angle 0°,\ \mathbf{V}_L = (I\ \angle 0°)(X_L\ \angle 90°)$

$= (6\ A\ \angle 0°)(200\ \Omega\ \angle 90°)$

$= \mathbf{1200\ V\ \angle 90°}$

$\mathbf{V}_C = (I\ \angle 0°)(X_C\ \angle -90°) = \mathbf{1200\ V\ \angle -90°}$

e. $P = I^2R = (6\ A)^2\ 5\ \Omega = \mathbf{180\ W}$

8. a. $BW = 6000\ Hz - 5400\ Hz = \mathbf{600\ Hz}$

b. $BW = f_s/Q_s \Rightarrow f_s = Q_sBW = (9.5)(600\ Hz) = \mathbf{5700\ Hz}$

c. $Q_s = \dfrac{X_L}{R} \Rightarrow X_L = X_C = Q_sR = (9.5)(2\ \Omega) = \mathbf{19\ \Omega}$

d. $L = \dfrac{X_L}{2\pi f} = \dfrac{19\ \Omega}{2\pi(5700\ Hz)} = \mathbf{0.531\ mH}$

$C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{2\pi(5.7\ kHz)(19\ \Omega)} = \mathbf{1.47\ \mu F}$

10. $Q_s = \dfrac{X_L}{R} \Rightarrow X_L = Q_sR = 20(2\ \Omega) = \mathbf{40\ \Omega} = X_C$

$BW = \dfrac{f_s}{Q_s} \Rightarrow f_s = Q_sBW = (20)(400\ Hz) = \mathbf{8\ kHz}$

$$L = \frac{X_L}{2\pi f} = \frac{40\ \Omega}{2\pi(8\text{ kHz})} = \mathbf{0.796\ mH}$$
$$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(8\text{ kHz})(40\ \Omega)} = \mathbf{0.497\ \mu F}$$

$$f_2 = f_s + BW/2 = 8000\text{ Hz} + 400\text{ Hz}/2 = \mathbf{8200\ Hz}$$
$$f_1 = f_s - BW/2 = 8000\text{ Hz} - 200\text{ Hz} = \mathbf{7800\ Hz}$$

12. a. $$Q_\ell = \frac{X_L}{R_\ell}$$
$$R_\ell = \frac{X_L}{Q_\ell} = \frac{2\pi fL}{Q_\ell} = \frac{2\pi(1\text{ MHz})(100\ \mu\text{H})}{12.5} = 50.27\ \Omega$$
$$\frac{f_2 - f_1}{f_s} = \frac{1}{Q_s} = 0.2$$
$$Q_s = \frac{1}{0.2} = 5 = \frac{X_L}{R} = \frac{2\pi fL}{R} = \frac{2\pi(1\text{ MHz})(100\ \mu\text{H})}{R} = \frac{628.32\ \Omega}{R}$$
$$R = \frac{628.32\ \Omega}{5} = 125.66$$
$$R = R_d + R_\ell$$
$$125.66\ \Omega = R_d + 50.27\ \Omega$$
and $R_d = 125.66\ \Omega - 50.27\ \Omega = \mathbf{75.39\ \Omega}$

c. $$X_C = \frac{1}{2\pi fC} = X_L$$
$$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(1\text{ MHz})(628.32\ \Omega)} = \mathbf{253.3\ pF}$$

14. a. $$f_s = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(0.5\text{ mH})(30\text{ nF})}} = \mathbf{41.09\ kHz}$$

b. $$Q_\ell = \frac{X_L}{R_\ell} = \frac{2\pi fL}{R_\ell} = \frac{2\pi(41.09\text{ kHz})(0.5\text{ mH})}{8\ \Omega} = \mathbf{16.14} \geq 10\text{ (yes)}$$

c. Since $Q_\ell \geq 10, f_p \cong f_s = \mathbf{41.09\ kHz}$

d. $$X_L = 2\pi f_p L = 2\pi(41.09\text{ kHz})(0.5\text{ mH}) = \mathbf{129.1\ \Omega}$$
$$X_C = \frac{1}{2\pi f_p C} = \frac{1}{2\pi(41.09\text{ kHz})(30\text{ nF})} = \mathbf{129.1\ \Omega}$$
$$X_L = X_C$$

e. $$Z_{T_p} = Q_\ell^2 R\ell = (16.14)^2\ 8\ \Omega = \mathbf{2.084\ k\Omega}$$

f. $$V_C = IZ_{T_p} = (10\text{ mA})(2.084\text{ k}\Omega) = \mathbf{20.84\ V}$$

g. $Q_\ell \geq 10,\ Q_p = Q_\ell = \mathbf{16.14}$
$$BW = \frac{f_p}{Q_p} = \frac{41.09\text{ kHz}}{16.14} = \mathbf{2545.85\ Hz}$$

h. $I_L = I_C = Q_\ell I_T = (16.14)(10\text{ mA}) = \mathbf{161.4\text{ mA}}$

16. a. $Q_\ell = \dfrac{X_L}{R_L} = \dfrac{100\ \Omega}{20\ \Omega} = 5 \leq 10$

$$\therefore \frac{X_L}{R_\ell^2 + X_L^2} = \frac{1}{X_C} \Rightarrow X_C = \frac{R_\ell^2 + X_L^2}{X_L} = \frac{(20\ \Omega)^2 + (100\ \Omega)^2}{100\ \Omega} = \mathbf{104\ \Omega}$$

b. $Z_T = R_s \| R_p = R_s \| \dfrac{R_\ell^2 + X_L^2}{R_\ell} = 1000\ \Omega \| \dfrac{10{,}400\ \Omega}{20} = \mathbf{342.11\ \Omega}$

c. $\mathbf{E} = \mathbf{I}\mathbf{Z}_{T_p} = (5\text{ mA} \angle 0°)(342.11\ \Omega \angle 0°) = 1.711\text{ V} \angle 0°$

$$\mathbf{I}_C = \frac{\mathbf{E}}{X_C \angle -90°} = \frac{1.711\text{ V} \angle 0°}{104\ \Omega \angle -90°} = \mathbf{16.45\text{ mA} \angle 90°}$$

$$\mathbf{Z}_L = 20\ \Omega + j100\ \Omega = 101.98\ \Omega \angle 78.69°$$

$$\mathbf{I}_L = \frac{\mathbf{E}}{\mathbf{Z}_L} = \frac{1.711\text{ V} \angle 0°}{101.98\ \Omega \angle 78.69°} = \mathbf{16.78\text{ mA} \angle -78.69°}$$

d. $L = \dfrac{X_L}{2\pi f} = \dfrac{100\ \Omega}{2\pi(20\text{ kHz})} = \mathbf{0.796\text{ mH}}$

$$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(20\text{ kHz})(104\ \Omega)} = \mathbf{76.52\text{ nF}}$$

e. $Q_p = \dfrac{R}{X_C} = \dfrac{342.11\ \Omega}{104\ \Omega} = \mathbf{3.29}$

$$BW = f_p/Q_p = 20{,}000\text{ Hz}/3.29 = \mathbf{6079.03\text{ Hz}}$$

18. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(80\ \mu\text{H})(0.03\ \mu\text{F})}} = \mathbf{102.73\text{ kHz}}$

$$f_p = f_s\sqrt{1 - \frac{R_\ell^2 C}{L}} = 102.73\text{ kHz}\sqrt{1 - \frac{(1.5\ \Omega)^2\ 0.03\ \mu\text{F}}{80\ \mu\text{H}}} = 102.73\text{ kHz}(.99958)$$

$$= \mathbf{102.69\text{ kHz}}$$

$$f_m = f_s\sqrt{1 - \frac{1}{4}\left[\frac{R_\ell^2 C}{L}\right]} = 102.73\text{ kHz}(0.99989) = \mathbf{102.72\text{ kHz}}$$

Since $f_s \cong f_p \cong f_m \Rightarrow$ high Q_p

b. $X_L = 2\pi f_p L = 2\pi(102.69\text{ kHz})(80\ \mu\text{H}) = \mathbf{51.62\ \Omega}$

$$X_C = \frac{1}{2\pi f_p C} = \frac{1}{2\pi(102.69\text{ kHz})(0.03\ \mu\text{F})} = \mathbf{51.66\ \Omega}$$

$$X_L \cong X_C$$

c. $Z_{T_p} = R_s \| Q_\ell^2 R_\ell$

$$Q_\ell = \frac{X_L}{R_\ell} = \frac{51.62\ \Omega}{1.5\ \Omega} = 34.41$$

$$Z_{T_p} = 10\ \text{k}\Omega \| (34.41)^2 1.5\ \Omega = 10\ \text{k}\Omega \| 1.776\ \text{k}\Omega = \mathbf{1.51\ k\Omega}$$

d. $$Q_p = \frac{R_s \| Q_\ell^2 R_\ell}{X_L} = \frac{Z_{T_p}}{X_L} = \frac{1.51\ \text{k}\Omega}{51.62\ \Omega} = \mathbf{29.25}$$

$$BW = \frac{f_p}{Q_p} = \frac{102.69\ \text{kHz}}{29.25} = \mathbf{3.51\ kHz}$$

e. $$I_T = \frac{R_s I_s}{R_s + Q_\ell^2 R_\ell} = \frac{10\ \text{k}\Omega(10\ \text{mA})}{10\ \text{k}\Omega + 1.78\ \text{k}\Omega} = 8.49\ \text{mA}$$

$$I_C = I_L \cong Q_\ell I_T = (34.41)(8.49\ \text{mA}) = \mathbf{292.14\ mA}$$

f. $$V_C = IZ_{T_p} = (10\ \text{mA})(1.51\ \text{k}\Omega) = \mathbf{15.1\ V}$$

20. a. $$Z_{T_p} = \frac{R_\ell^2 + X_L^2}{R_\ell} = 50\ \text{k}\Omega$$

$$(50\ \Omega)^2 + X_L^2 = (50\ \text{k}\Omega)(50\ \Omega)$$

$$X_L = \sqrt{250 \times 10^4 - 2.5 \times 10^3} = \mathbf{1580.3\ \Omega}$$

b. $$Q = \frac{X_L}{R_\ell} = \frac{1580.3}{50} = 31.61 \geq 10$$

$$\therefore X_C = X_L = \mathbf{1580.3\ \Omega}$$

c. $$X_L = 2\pi f_p L \Rightarrow f_p = \frac{X_L}{2\pi L} = \frac{1580.3\ \Omega}{2\pi(16\ \text{mH})} = \mathbf{15.72\ kHz}$$

d. $$X_C = \frac{1}{2\pi f_p C} \Rightarrow C = \frac{1}{2\pi f_s X_C} = \frac{1}{2\pi(15.72\ \text{kHz})(1580.3\ \Omega)} = \mathbf{6.4\ nF}$$

22. a. Ratio of X_C to R_ℓ suggests high Q system.

$\therefore X_L = \mathbf{400\ \Omega} = X_C$

b. $$Q_\ell = \frac{X_L}{R_\ell} = \frac{400\ \Omega}{8\ \Omega} = \mathbf{50}$$

c. $$Q_p = \frac{R}{X_L} = \frac{R_s \| R_p}{X_L} = \frac{R_s \| Q_\ell^2 R_\ell}{X_L} = \frac{20\ \text{k}\Omega \| (50)^2\ 8\ \Omega}{400\ \Omega} = \frac{10\ \text{k}\Omega}{400\ \Omega} = \mathbf{25}$$

$$BW = \frac{f_p}{Q_p} \Rightarrow f_p = Q_p BW = (25)(1000\ \text{Hz}) = \mathbf{25\ kHz}$$

d. $$V_{C_{\max}} = IZ_{T_p} = (0.1\ \text{mA})(10\ \text{k}\Omega) = \mathbf{1\ V}$$

e. $f_2 = f_p + BW/2 = 25\text{ kHz} + \dfrac{1\text{ kHz}}{2} = \mathbf{25.5\text{ kHz}}$

$f_1 = f_p - BW/2 = 25\text{ kHz} - \dfrac{1\text{ kHz}}{2} = \mathbf{24.5\text{ kHz}}$

24. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(0.5\text{ mH})(30\text{ nF})}} = \mathbf{41.09\text{ kHz}}$

$$f_p = f_s\sqrt{1 - \frac{R_\ell^2 C}{L}} = 41.09\text{ kHz}\sqrt{1 - \frac{(6\ \Omega)^2\ 30\text{ nF}}{0.5\text{ mH}}} = 41.09\text{ kHz}(0.9978) = \mathbf{41\text{ kHz}}$$

$$f_m = f_s\sqrt{1 - \frac{1}{4}\left[\frac{R_\ell^2 C}{L}\right]} = 41.09\text{ kHz}\sqrt{1 - \frac{1}{4}\left[\frac{(6\ \Omega)^2(30\text{ nF})}{0.5\text{ mH}}\right]} = 41.09\text{ kHz}(0.0995)$$
$$= \mathbf{41.07\text{ kHz}}$$

b. $\mathbf{I} = \dfrac{80\text{ V}\ \angle 0°}{20\text{ k}\Omega\ \angle 0°} = 4\text{ mA}\ \angle 0°,\ R_s = 20\text{ k}\Omega$

$$Q_\ell = \frac{X_L}{R_\ell} = \frac{2\pi fL}{R_\ell} = \frac{2\pi(41\text{ kHz})(0.5\text{ mH})}{6\ \Omega} = \mathbf{21.47}\text{ (high } Q \text{ coil)}$$

$$Q_p = \frac{R_s \| R_p}{X_{L_p}} = \frac{R_s \| \dfrac{R_\ell^2 + X_L^2}{R_\ell}}{\dfrac{R_\ell^2 + X_L^2}{X_L}} = \frac{20\text{ k}\Omega \| \dfrac{(6\ \Omega)^2 + (128.81\ \Omega)^2}{6\ \Omega}}{\dfrac{(6\ \Omega)^2 + (128.81\ \Omega)^2}{128.81\ \Omega}}$$
$$= \frac{20\text{ k}\Omega \| 2.771\text{ k}\Omega}{129.09\ \Omega} = \frac{2.434\text{ k}\Omega}{129.09\ \Omega} = \mathbf{18.86}\text{ (high } Q_p)$$

c. $Z_{T_p} = R_s \| R_p = 20\text{ k}\Omega \| 2.771\text{ k}\Omega = \mathbf{2.434\text{ k}\Omega}$

d. $V_C = IZ_{T_p} = (4\text{ mA})(2.434\text{ k}\Omega) = \mathbf{9.736\text{ V}}$

e. $BW = \dfrac{f_p}{Q_p} = \dfrac{41\text{ kHz}}{18.86} = \mathbf{2.174\text{ kHz}}$

f. $X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(41\text{ kHz})(30\text{ nF})} = \mathbf{129.39\ \Omega}$

$I_C = \dfrac{V_C}{X_C} = \dfrac{9.736\text{ V}}{129.39\ \Omega} = \mathbf{75.25\text{ mA}}$

$I_L = \dfrac{V_C}{|R + jX_L|} = \dfrac{9.736\text{ V}}{6\ \Omega + j128.81\ \Omega} = \dfrac{9.736\text{ V}}{128.95\ \Omega} = \mathbf{75.50\text{ mA}}$

26. $V_{C_{max}} = IZ_{T_p} \Rightarrow Z_{T_p} = \dfrac{V_{C_{max}}}{I} = \dfrac{1.8\text{ V}}{0.2\text{ mA}} = 9\text{ k}\Omega$

$$Q_p = \frac{R}{X_L} = \frac{R_s \| R_p}{X_L} = \frac{R_p}{X_L} \Rightarrow X_L = \frac{R_p}{Q_p} = \frac{9\text{ k}\Omega}{30} = \mathbf{300\ \Omega} = X_C$$

$$BW = \frac{f_p}{Q_p} \Rightarrow f_p = Q_p BW = (30)(500\text{ Hz}) = \mathbf{15\text{ kHz}}$$

$$L = \frac{X_L}{2\pi f} = \frac{300\ \Omega}{2\pi(15\text{ kHz})} = \mathbf{3.18\text{ mH}}$$

$$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(15\text{ kHz})(300\ \Omega)} = \mathbf{35.37\text{ nF}}$$

$$Q_p = Q_\ell(R_s = \infty\ \Omega) = \frac{X_L}{R_\ell} \Rightarrow R_\ell = \frac{X_L}{Q_p} = \frac{300\ \Omega}{30} = \mathbf{10\ \Omega}$$